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ON
THE GRAPHITE
OF
THE LAURENTIAN OF CANADA.

BY
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In my paper of 1864, on the Organic Remains of the Laurentian Limestones of Canada, as a sequel to the description of *Eozoon Canadense*, I noticed, among other indications of organic matters in these limestones, the presence of films and fibres of graphitic matter, and insisted on the probability that at least some of the lower forms of plant life must have existed in the seas in which gigantic Foraminifera could flourish. Dr. Hunt had previously, on chemical evidence, inferred the existence of Laurentian vegetation*, and Dana had argued as to the probability of this on various grounds†; and my object in referring to these indications in 1864, as well as to the supposed burrows of annelids, subsequently described by me ‡, was to show that the occurrence of *Eozoon* was not to be regarded as altogether isolated and unsupported by probabilities of the existence of organic remains in the Laurentian deducible from other considerations.

Now that the questions which have been raised regarding *Eozoon*

* 'American Journal of Science' (2), xxxi. p. 395. From this article, written in 1861, after the announcement of the existence of laminated forms supposed to be organic in the Laurentian, by Sir W. E. Logan, but before their structure and affinities had been ascertained, I quote the following sentences:—"We see in the Laurentian series beds and veins of metallic sulphurets, precisely as in more recent formations; and the extensive beds of iron-ore, hundreds of feet thick, which abound in that ancient system, correspond not only to great volumes of strata deprived of that metal, but, as we may suppose, to organic matters which, but for the then great diffusion of iron-oxyd in conditions favourable for their oxydation, might have formed deposits of mineral carbon far more extensive than those beds of plumbago which we actually meet in the Laurentian strata. All these conditions lead us then to conclude the existence of an abundant vegetation during the Laurentian period."

† Manual of Geology. I may also be permitted to refer to my own work 'Archaea,' p. 168, and Appendix D, 1860.

‡ Quart. Journ. Geol. Soc. vol. xxii. p. 608.

may be considered settled, not only by the adhesion of the greatest authorities in paleontology and zoology, but by the discovery of similar organisms in rocks of the same age elsewhere, by specimens preserved in such a manner as to avoid all the objections raised to the mineral condition of the fossil*, and by the discovery of such modern analogies as that furnished by *Bathybius*, it may be proper to invite the attention of geologists more particularly to the evidence of vegetable life afforded by the deposits of graphite existing in the Laurentian.

The graphite of the Laurentian of Canada occurs both in beds and in veins, and in such a manner as to show that its origin and deposition are contemporaneous with those of the containing rock. Sir William Logan states† that "the deposits of plumbago generally occur in the limestones or in their immediate vicinity, and granular varieties of the rock often contain large crystalline plates of plumbago. At other times this mineral is so finely disseminated as to give a bluish-gray colour to the limestone, and the distribution of bands thus coloured, seems to mark the stratification of the rock." He further states:—"The plumbago is not confined to the limestones; large crystalline scales of it are occasionally disseminated in pyroxene rock or pyrallolite, and sometimes in quartzite and in feldspathic rocks, or even in magnetic oxide of iron." In addition to these bedded forms, there are also true veins in which graphite occurs associated with calcite, quart, orthoclase, or pyroxene, and either in disseminated scales, in detached masses, or in bands or layers "separated from each other, and from the wall rock by feldspar, pyroxene, and quartz." Dr. Hunt also mentions the occurrence of finely granular varieties, and of that peculiarly waved and corrugated variety simulating fossil wood, though really a mere form of laminated structure, which also occurs at Warrensburgh, New York, and at the Marinski mine in Siberia. Many of the veins are not true fissures, but rather constitute a net-work of shrinkage cracks or segregation veins traversing in countless numbers the containing rock, and most irregular in their dimensions, so that they often resemble strings of nodular masses. It has been supposed that the graphite of the veins was originally introduced as a liquid hydro-carbon. Dr. Hunt, however, regards it as possible that it may have been in a state of aqueous solution‡; but in whatever way introduced, the character of the veins indicates that in the case of the greater number of them the carbonaceous material must have been derived from the bedded rocks traversed by these veins, while there can be no doubt that the graphite found in the beds has

* I cannot, after examination of the specimen, and of others subsequently obtained by Sir W. E. Logan, attach any value to the supposition of Messrs. Rowney & King that the Tudor specimen has been produced by infiltration of carbonate of lime into veins. The mechanical arrangement of the laminae and their microscopic structure forbid such a supposition, as well as the comparison of them with actual calcareous veins occurring in the same rock.

† 'Geology of Canada,' 1863.

‡ 'Report of the Geological Survey of Canada,' 1866.

been deposited along with the calcareous matter or muddy and sandy sediment of which these beds were originally composed.

The quantity of graphite in the Lower Laurentian series is enormous. In a recent visit to the township of Buckingham, on the Ottawa River, I examined a band of limestone believed to be a continuation of that described by Sir W. E. Logan as the Green Lake Limestone. It was estimated to amount, with some thin interstratified bands of gneiss, to a thickness of 600 feet or more, and was found to be filled with disseminated crystals of graphite and veins of the mineral to such an extent as to constitute in some places one-fourth of the whole; and making every allowance for the poorer portions, this band cannot contain in all a less vertical thickness of pure graphite than from 20 to 30 feet. In the adjoining township of Lochaber Sir W. E. Logan notices a band from 25 to 30 feet thick, reticulated with graphite veins to such an extent as to be mined with profit for the mineral. At another place in the same district a bed of graphite from 10 to 12 feet thick, and yielding 20 per cent. of the pure material, is worked. When it is considered that graphite occurs in similar abundance at several other horizons, in beds of limestone which have been ascertained by Sir W. E. Logan to have an aggregate thickness of 3500 feet, it is scarcely an exaggeration to maintain that the quantity of carbon in the Laurentian is equal to that in similar areas of the Carboniferous System. It is also to be observed that an immense area in Canada appears to be occupied by these graphitic and *Eozoon*-limestones, and that rich graphitic deposits exist in the continuation of this system in the State of New York, while in rocks believed to be of this age near St. John, New Brunswick, there is a very thick bed of graphitic limestone, and associated with it three regular beds of graphite, having an aggregate thickness of about 5 feet*.

It may fairly be assumed that in the present world and in those geological periods with whose organic remains we are more familiar than with those of the Laurentian, there is no other source of un-oxidized carbon in rocks than that furnished by organic matter, and that this has obtained its carbon in all cases, in the first instance, from the deoxidation of carbonic acid by living plants. No other source of carbon can, I believe, be imagined in the Laurentian period. We may, however, suppose either that the graphitic matter of the Laurentian has been accumulated in beds like those of coal, or that it has consisted of diffused bituminous matter similar to that in more modern bituminous shales and bituminous and oil-bearing limestones. The beds of graphite near St. John, some of those in the gneiss at Ticonderoga in New York, and at Lochaber and Buckingham and elsewhere in Canada are so pure and regular that one might fairly compare them with the graphitic coal of Rhode Island. These instances, however, are exceptional, and the greater part of the disseminated and vein graphite might rather be compared in its

* Matthew in 'Quart. Journ. Geol. Soc.' vol. xxi. p. 423. Acadian Geology, p. 662.

mode of occurrence to the bituminous matter in bituminous shales and limestones.

We may compare the disseminated graphite to that which we find in those districts of Canada in which Silurian and Devonian bituminous shales and limestones have been metamorphosed and converted into graphitic rocks not dissimilar to those in the less altered portions of the Laurentian*. In like manner it seems probable that the numerous reticulating veins of graphite may have been formed by the segregation of bituminous matter into fissures and planes of least resistance, in the manner in which such veins occur in modern bituminous limestones and shales. Such bituminous veins occur in the Lower Carboniferous limestone and shale of Dorchester and Hillsborough, New Brunswick, with an arrangement very similar to that of the veins of graphite; and in the Quebec rocks of Point Levi, veins attaining to a thickness of more than a foot, are filled with a coaly matter having a transverse columnar structure and regarded by Logan and Hunt as an altered bitumen. These palaeozoic analogies would lead us to infer that the larger part of the Laurentian graphite falls under the second class of deposits above mentioned, and that, if of vegetable origin, the organic matter must have been thoroughly disintegrated and bituminized before it was changed into graphite. This would also give a probability that the vegetation implied was aquatic, or at least that it was accumulated under water.

Dr. Hunt has, however, observed an indication of terrestrial vegetation, or at least of subaerial decay, in the great beds of Laurentian iron-ore. These, if formed in the same manner as more modern deposits of this kind, would imply the reducing and solvent action of substances produced in the decay of plants. In this case such great ore beds as that of Hull, on the Ottawa, 70 feet thick, or that near Newborough, 200 feet thick†, must represent a corresponding quantity of vegetable matter which has totally disappeared. It may be added that similar demands on vegetable matter as a deoxidizing agent are made by the beds and veins of metallic sulphides of the Laurentian, though some of the latter are no doubt of later date than the Laurentian rocks themselves.

It would be very desirable to confirm such conclusions as those above deduced by the evidence of actual microscopic structure. It is to be observed, however, that when, in more modern sediments, Alge have been converted into bituminous matter, we cannot ordinarily obtain any structural evidence of the origin of such bitumen, and in the graphitic slates and limestones derived from the metamorphosis of such rocks no organic structure remains. It is true that, in certain bituminous shales and limestones of the Silurian system, shreds of organic tissue can sometimes be detected, and in some cases, as in the Lower Silurian limestone of the La Cloche mountains in Canada, the pores of brachiopodous shells and the cells of corals have been penetrated by black bituminous matter, forming

* Granby, Melbourne, Owl's Head, &c., 'Geology of Canada,' 1863, p. 599.

† Geology of Canada, 1863.

what may be regarded as natural injections, sometimes of much beauty. In correspondence with this, while in some Laurentian graphitic rocks, as, for instance, in the compact graphite of Clarendon, the carbon presents a curdled appearance due to segregation, and precisely similar to that of the bitumen in more modern bituminous rocks, I can detect in the graphitic limestones occasional fibrous structures which may be remains of plants, and in some specimens vermicular lines, which I believe to be tubes of *Eozoon* penetrated by matter once bituminous, but now in the state of graphite.

When palaeozoic land-plants have been converted into graphite, they sometimes perfectly retain their structure. Mineral charcoal, with structure, exists in the graphitic coal of Rhode Island. The fronds of ferns, with their minutest veins perfect, are preserved in the Devonian shales of St. John, in the state of graphite; and in the same formation there are trunks of Conifers (*Dadoxylon onangondianum*) in which the material of the cell-walls has been converted into graphite, while their cavities have been filled with calcareous spar and quartz, the finest structures being preserved quite as well as in comparatively unaltered specimens from the coal-formation*. No structures so perfect have as yet been detected in the Laurentian, though in the largest of the three graphitic beds at St. John there appear to be fibrous structures, which I believe may indicate the existence of land-plants. This graphite is composed of contorted and slickensided laminae, much like those of some bituminous shales and coarse coals; and in these there are occasional small pyritous masses which show hollow carbonaceous fibres, in some cases presenting obscure indications of lateral pores. I regard these indications, however, as uncertain; and it is not as yet fully ascertained that these beds at St. John are on the same geological horizon with the Lower Laurentian of Canada, though they certainly underlie the Primordial series of the Acadian group, and are separated from it by beds having the character of the Huronian.

There is thus no absolute impossibility that distinct organic tissues may be found in the Laurentian graphite, if formed from land-plants, more especially if any plants existed at that time having true woody or vascular tissues; but it cannot with certainty be affirmed that such tissues have been found. It is possible, however, that in the Laurentian period the vegetation of the land may have consisted wholly of cellular plants, as, for example, mosses and lichens; and if so, there would be comparatively little hope of the distinct preservation of their forms or tissues, or of our being able to distinguish the remains of land-plants from those of Algae.

We may sum up these facts and considerations in the following statements:—First, that somewhat obscure traces of organic structure can be detected in the Laurentian graphite; secondly, that the general arrangement and microscopic structure of the substance corresponds with that of the carbonaceous and bituminous matters in

* *Acadian Geology*, p. 535. In calcified specimens the structures remain in the graphite after decalcification by an acid.

marine formations of more modern date; thirdly, that if the Laurentian graphite has been derived from vegetable matter, it has only undergone a metamorphosis similar in kind to that which organic matter in metamorphosed sediment of later age has experienced; fourthly, that the association of the graphitic matter with organic limestone, beds of iron ore, and metallic sulphides greatly strengthens the probability of its vegetable origin; fifthly, that when we consider the immense thickness and extent of the Eozonal and graphitic limestones and iron-ore deposits of the Laurentian, if we admit the organic origin of the limestone and graphite, we must be prepared to believe that the life of that early period, though it may have existed under low forms, was most copiously developed, and that it equalled, perhaps surpassed, in its results, in the way of geological accumulation, that of any subsequent period.

In conclusion, this subject opens up several interesting fields of chemical, physiological, and geological inquiry. One of these relates to the conclusions stated by Dr. Hunt as to the probable existence of a large amount of carbonic acid in the Laurentian atmosphere, and of much carbonate of lime in the seas of that period, and the possible relation of this to the abundance of certain low forms of plants and animals. Another is the comparison already instituted by Professor Huxley and Dr. Carpenter, between the conditions of the Laurentian and those of the deeper parts of the modern ocean. Another is the possible occurrence of other forms of animal life than *Eozoon* and Annelids, which I have stated in my paper of 1864, after extensive microscopic study of the Laurentian limestones, to be indicated by the occurrence of calcareous fragments, differing in structure from *Eozoon*, but at present of unknown nature. Another is the effort to bridge over, by further discoveries similar to that of the *Eozoon bavaricum* of Gümbel, the gap now existing between the life of the Lower-Laurentian and that of the Primordial Silurian or Cambrian period. It is scarcely too much to say that these inquiries open up a new world of thought and investigation, and hold out the hope of bringing us into the presence of the actual origin of organic life on our planet, though this may perhaps be found to have been Prelaurentian. I would here take the opportunity of stating that, in proposing the name *Eozoon* for the first fossil of the Laurentian, and in suggesting for the period the name "Eozoic," I have by no means desired to exclude the possibility of forms of life which may have been precursors of what is now to us the dawn of organic existence. Should remains of still older organisms be found in those rocks now known to us only by pebbles in the Laurentian, these names will at least serve to mark an important stage in geological investigation.
